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INSTRUCTION BOOK

for

MODEL 393
HIGH FREQUENCY
TRANSFER VOLTMETER

BALLANTINE LABORATORIES, INC.
BOONTON, NEW JERSEY

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TRANSFER VOLTMETER

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY

PRINTED IN U.S.A.

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WARRANTY

Each Ballantine Laboratories, Inc. instrument, or part thereof, is warranted to be free from defects in material and workmanship. Ballantine Laboratories, Inc. obligation under this warranty is limited to repairing or replacing any instrument or part thereof, except vacuum tubes and batteries, which shall within one year after shipment to the original purchaser prove upon Ballantine Laboratories, Inc. examination to have become defective.

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FOR

MODEL 393 HIGH FREQUENCY TRANSFER VOLTMETER

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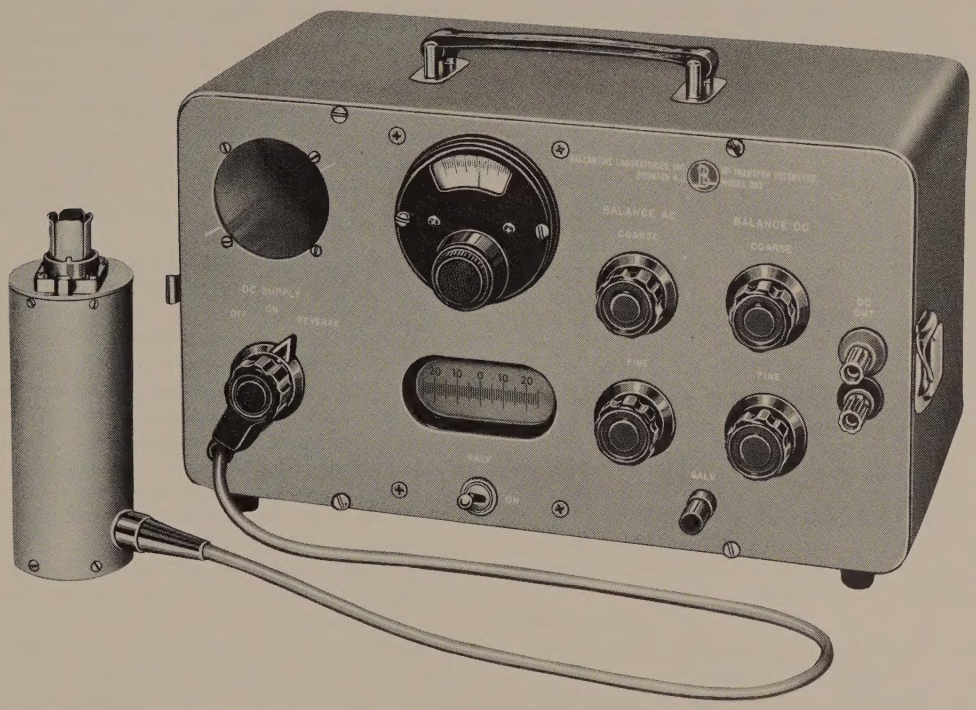


Fig. 1 Model 393 High Frequency Transfer Voltmeter

1. GENERAL INFORMATION

1.1 Purpose and Use

The Ballantine Model 393 is a High Frequency Transfer Voltmeter designed to measure ac voltages with standards laboratory accuracy from 1 V to 50 V, over a frequency range of 25 cps to 30 Mc. It utilizes a transfer principle for measurement, by which the unknown ac voltage is equated to dc voltages which may be measured by accurate dc measuring equipment. The transfer from ac to dc is made in a thermocouple which is an rms responding device. Therefore, the true rms value of the unknown ac voltage is measured.

The transfer accuracy of the Model 393 is based on passive components which are not subject to aging or changes when properly used. The effect of most component changes is eliminated by using the transfer principle. Thus, the Model 393 is a device suitable for Standards Laboratory use.

Besides absolute voltage measurements, the Model 393 is invaluable for frequency response measurements of vtvm's and similar devices. In this capacity it presents a welcome extension to the Ballantine Model 440 Micropotentiometer which allows similar measurements from microvolt ranges up to 0.3 V. The Model 393 extends this range to 50 V.

The instrument consists of the Model 393 Transfer Unit and a set of 5 probes. The Transfer Unit houses the galvanometer and batteries, with related circuitry needed for accurate ac to dc transfer. It also contains a stable 5 V dc source. For higher voltage measurements an external dc source is required. The unit is designed for simple and safe operation. It is completely self-powered. The only accessory needed is an accurate dc voltmeter or Type K potentiometer.

The probes cover each 1 ÷ 2.5 voltage range. Each probe consists of a stable measuring resistor and a uhf thermocouple. The probes are interchangeable.

The basic hf transfer concept was developed by Mr. F. L. Hermach of the National Bureau of Standards and is described in his AIEE conference paper CP-59-876, "Thermal Voltage Converters for Accurate Voltage Measurements to 30 Mc."

1.2 Technical Characteristics

PROBES

AC voltage range: 1 volt to 50 volts
Frequency range: 25 cps to 30 Mc
Accuracy of frequency response: 0.1% — 25 cps to 10 Mc
0.5% — 10 Mc to 30 Mc

Thermocouple

Nominal thermocouple current — 5 mA
Max safe thermocouple current — 7.5 mA
Nominal open circuit output emf for 5 mA current — 7 mV.

Designation, Voltage Range, and DC Input Resistance

Model Designation	Voltage Range	DC Input Resistance ohms ± 5%
1393-2	1 V to 2 V	400
1393-5	2 V to 5 V	1000
1393-10	5 V to 10 V	2000
1393-20	10 V to 20 V	4000
1393-50	20 V to 50 V	10000

Input Capacitance — 2.7/5 pF (See Sec. 2.5)

TRANSFER UNIT

AC Balance Range

Max thermocouple current 5 mA (7 mV couple output)
Min thermocouple current 2 mA (1.1 mV couple output)
Balance indicator — Light Beam Galvanometer
Sensitivity 0.2 μA/mm

DC Supply

2 V Range — Source resistance 2.2 to 2.5 kΩ
Output divider 1 to 2, ± 0.05%
5 V Range — Source resistance 0.9 to 1.1 kΩ
Output divider 1 to 5, ± 0.05%
External supply required for measurements above 5 volts

Reversal Switch to reverse the polarity to the dc supply provided

Internal Batteries

6 Mallory type RM4RT or equal
1 Eveready type 142 or equal

Length of Cable To Probe 24 inches

ADDITIONAL INFORMATION

Dimensions Of Transfer Unit (6⅞ in. wide X 7½ in. deep X 12⅜ in. long)

Weight with five probes, 16 pounds

Shipping Weight with five probes, 30 pounds

Color, Gray

19 inch relay rack version is available.

2. OPERATION

2.1 Starting Procedure

The Model 393 is supplied with batteries and is ready to operate as received. To allow the batteries to stabilize, the DC SUPPLY should be switched to ON approximately 5 minutes before a measurement is made. When the batteries are used for the first time, a 15-30 minute stabilizing period is required.

During transportation, the galvanometer light switch should be always in the OFF position. This shunts the galvanometer, and avoids damage from mechanical shock or vibration.

2.2 Function of Controls

DC SUPPLY	Switches the dc (B3-B7) and bucking (B1) batteries.
OFF	All batteries are switched off.
ON	All batteries are on, with positive polarity to the probe.
REVERSE	All batteries are on, with negative polarity to the probe.
BALANCE AC	Galvanometer bucking controls, which
COARSE	are set for no galvanometer deflection
FINE	when the probe is connected to an ac source.

BALANCE DC COARSE FINE	Internal dc source voltage controls; are set for no galvanometer deflection when the probe is inserted into the probe holder.
TOGGLE SWITCH GALV ON OFF	Switches the galvanometer light on. Shorts the galvanometer for transportation.
PUSHBUTTON SWITCH GALV	When depressed, connects the galvanometer into the balance circuit.
DC OUT	Divided dc output for external voltmeter.

2.3 Voltage Measurements with 2 V and 5 V Probes may be made using the internal dc supply as a transfer source.

2.3.1 — For such measurement, select a probe with the proper voltage range. Connect the probe to the probe cable. Turn the DC SUPPLY to ON for at least 5 minutes before measurement.

2.3.2 — Connect the probe to the source to be measured. Use the proper adapter, or as short connections as possible, when the source does not have a GR Type 874 connector. Allow approx. 1 - 2 minutes warmup time for the thermocouple heater, switch the galvanometer toggle switch to ON, depress the GALV pushbutton switch and adjust BALANCE AC COARSE AND FINE until the light beam shows no deflection.

2.3.3 — A one division deflection on the light beam scale of the galvanometer corresponds to a 0.1% to 0.4% input voltage deviation from the correct balance depending on whether the probe is used at the maximum or minimum voltage in its range. Therefore, for accurate results, the galvanometer deflection should be balanced out to 1/10 to 2/10 of a division.

2.3.4 — Connect the probe to the internal dc supply by inserting it into the holder cavity in the Model 393 panel. The probe fits into the holder in only 2 positions, in each of which the radial lines on the panel will line up with the probe output connector. *The probe should not be forced into the holder in any other position;* to do so may cause damage to the connector inside the probe holder.

The 5 V probe has two posts on the front face which activate a switch inside the probe holder to change the internal dc supply to 5 V. To assure proper switching, the 5 V probe should always be firmly pressed into the holder until the switch is activated.

Adjust the BALANCE DC COARSE and FINE controls until the galvanometer light beam shows no deflection when the GALV pushbutton is depressed. The voltage from internal dc supply now equals the rms value of the ac voltage previously applied to the probe.

2.3.5. — Connect an accurate, 1 V full range, 10 MΩ or higher input resistance dc voltmeter to the DC OUT terminals. Measure the dc output. This, when multiplied by a factor of

2 with 1 - 2 V (1393-2) probe, or
5 with 2 - 5 V (1393-5) probe

equals the unknown ac voltage.

When measuring the dc output, the probe should always be inserted into the holder.

The procedure described under 2.3.1 to 2.3.5 is shown in simplified form in the following figure 2.

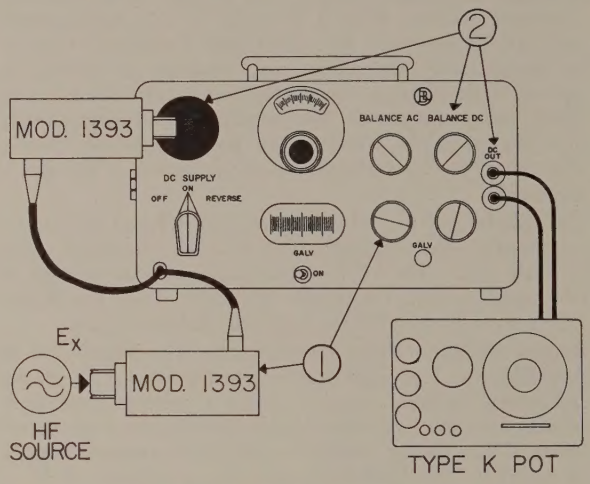


Figure 2. Voltage Measurements with 2 V and 5 V Probes.

1. Connect probe to the ac source, adjust BALANCE AC for no deflection on the galvanometer.
2. Insert probe into probe holder, adjust BALANCE DC for no deflection on the galvanometer. Measure DC OUT.

2.3.6 — The effect of the source resistance of DC OUT terminals is below 0.01% when the dc voltmeter input resistance is more than 10 MΩ in the 2 - 5 V range or 20 MΩ in the 1 - 2 V range. If the input resistance of the dc voltmeter used is below that value, a correction should be applied for best accuracy.

The source resistance of the dc output is 2.2 - 2.5 kΩ in the 1 - 2 V range (1393-2 probe), and 0.9 - 1.1 kΩ in the 2 - 5 V range (1393-5 probe).

The voltage drop in this resistance may be corrected with the following equation:

$$E_{DC} = E_M \left(1 + \frac{R_S}{R_V}\right)$$

E_{DC} = correct dc output (V)
E_M = measured dc output (V)
R_S = 2350 Ω with 1 - 2 V (1393-2) probe
1000 Ω with 2 - 5 V (1393-5) probe
R_V = DC Voltmeter input resistance (ohms)

2.4 Voltage Measurements with 10 V to 50 V Probes should be done using an external dc or low frequency ac supply. The supply should be able to deliver 5 mA into a 2 to 10 kΩ load, be stable to 0.01% over a 10 minute period and be adjustable over the voltage measuring range desired. The output adjustment should have a precision of 0.01% or better. An accurately calibrated dc supply or low frequency ac generator may be used which will eliminate the need for an external dc voltmeter.

2.4.1 — To make the measurement, connect the probe with the proper voltage range to the ac source to be measured. Adjust BALANCE AC COARSE and FINE until the galvanometer shows no deflection when the GALV pushbutton is depressed. (See 2.3.2; 2.3.3)

2.4.2 — Connect the probe to the external dc supply or low frequency ac source. Vary the supply voltage until galvanometer shows no deflection with the GALV pushbutton depressed. Measure the supply voltage accurately. The measured voltage equals the unknown ac voltage.

If a calibrated dc supply or low frequency ac source is used, the unknown voltage may be read directly from the setting of the supply.

If the voltage of dc supply or ac source is measured with an accurate voltmeter, the measurement should be done with the probe connected to the supply to take into account the loading effect of the probe if the supply has an appreciable source impedance.

The procedure described under 2.4.1 and 2.4.2 is shown simplified in figure 3.

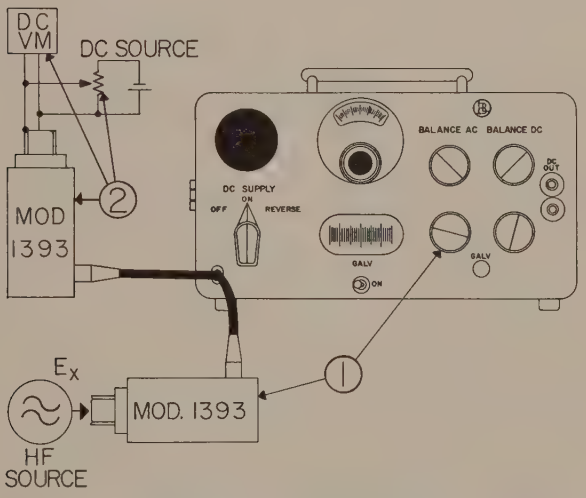


Figure 3. Voltage Measurements with 10 V and 50 V Probes.

1. Connect probe to the ac source, adjust BALANCE AC for no deflection on the galvanometer.
2. Connect probe to the external dc source. Adjust source voltage for no deflection on the galvanometer. Measure the external source voltage accurately.

2.5 Input Impedance and Plane of Reference

The input impedance of the probes may be represented by a parallel combination of resistance and capacitance. The values of both components remain practically constant throughout the frequency range of the probes.

The resistance value depends on the voltage range of the probe as follows:

Model No. of Probe	*Voltage Range (Volts)*	*Resistance (ohms)*
1393-2	1 - 2	400
1393-5	2 - 5	1000
1393-10	5 - 10	2000
1393-20	10 - 20	4000
1393-50	20 - 50	10000

The actual resistance value may differ up to ±5% from the nominal value given.

The probe's input capacitance depends upon the method of measurement. Measured at the tip of the connector, the input capacitance is 5 pF ±5%. However, when the probe is inserted into another GR Type 874 coaxial connection, it adds 2.7 pF ±5% capacitance to the connector.

The probes are calibrated at Ballantine Laboratories or NBS with the reference plane at the center of a GR Type 874-T adapter which is 2.7 cm distant from the front face of the connector. In a 50 ohm coaxial system at 30 Mc, this distance introduces less than 0.01% voltage variation.

The transmission line error at 30 Mc approaches 0.5% when the probe is connected to the source over 10 cm of a 50 Ω line. If the line is longer than 5 cm, a correction should be computed using standard transmission line equations.

2.6 Use of DC Reversal for More Accurate Measurements

When following the procedure described under 2.3 and 2.4, a small error up to 0.05% may be included in the measurement. This error is caused by a property of the thermocouple, such that when making ac-dc comparisons, the result depends on the direction of flow of the dc current. In one direction, the equivalent dc current is higher; in the other direction lower, than the true rms value of ac current. To reduce this error, the comparison should be made with dc in both directions and the average of the two measurements taken.

2.6.1 — With 2 V and 5 V probes using the internal dc supply, two measurements should be taken as described under 2.3.1 and 2.3.2. For the first measurement the DC SUPPLY switch should be in ON position; for the second measurement in REVERSE position. In this latter position the dc polarity to the probe is reversed. The red binding post of the DC OUT terminals for the external voltmeter is positive for both positions of the DC SUPPLY switch, so that reversal of the dc voltmeter is not required. An arithmetical average of both measurements should be taken. This represents the true equivalent of the measured ac voltages.

2.6.2 Example

Using 1393-5 (2 - 5 V) probe

0.73582 V DC was measured in ON position

0.73611 V DC was measured in REVERSE position

$$\frac{1.47193}{2} = 0.73596 \text{ or the average of two measurements}$$

With the 5 V probe, the multiplication factor is 5, so that the true ac voltage to the probe is

$$E_{AC} = 0.73596 \times 5 = 3.67980 \text{ V}$$

2.6.3 — When measuring above 5 V using an external dc source, two measurements with reversed dc polarity should be made, and an average of the measurements taken.

2.6.4 — When using an accurately calibrated low frequency ac source for transfer, the reversal error is eliminated and only one measurement is required.

2.7 Frequency Response Measurement of RF Voltmeters

A normal voltmeter calibration procedure consists of two steps:

a. Measurement of voltmeter accuracy at midband (0.4 - 1 kc)

b. Measuring additional frequency response error at higher frequencies.

The Model 393 is very suitable for maintaining an rf voltage constant and in checking the frequency response error of voltmeters.

For frequency response measurements:

2.7.1 — Connect a stable ac generator and a Model 1393 probe of the proper range to the input of the voltmeter under test. Use as short connections as possible between the probe and voltmeter to reduce transmission line error. Shielded coaxial connectors, or T adapters should be used whenever possible.

2.7.2 — Set the ac generator to a frequency of 400 cps to 1 kc, adjust the level to produce an indication at the desired scale point. Set the BALANCE AC controls until no deflection in the galvanometer is observed when the GALV pushbutton is depressed.

2.7.3 — Change the generator frequency to the desired calibration frequency, adjust the generator level until no deflection on galvanometer is observed with GALV pushbutton depressed. In this case the rf voltage equals the voltage set previously (under 2.7.2). Observe the indication on the voltmeter. The difference between the lf indication and this indication is the voltmeter response error at the set frequency.

2.7.4 — Without changing the BALANCE AC proceed to the next calibration frequency and measure the error as described under 2.7.3.

After checking all calibration frequencies, the low frequency signal as in 2.7.2 should be applied again and the agreement between Model 393 balance and voltmeter indication checked. If the indication on voltmeter does not agree with initial indication, an error in the original setting or drift in the voltmeter or Model 393 batteries has occurred. The latter should be corrected according to 4.4.

If the calibration procedure extends over a 10 minute period, intermediate checks against initial low frequency setting should be taken and BALANCE AC corrected if drifts appear.

2.7.5 — The procedure described under 2.7.1 - 2.7.4 is shown in simplified form in the following figure 4.

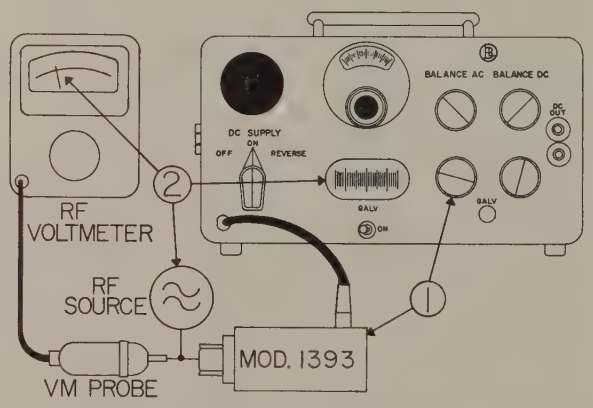


Figure 4. Frequency Response Measurement of RF Voltmeters.

1 — Set rf source at 0.4 - 1 kc, to give the desired indication on rf voltmeter. Adjust BALANCE AC for no deflection in galvanometer.

2 — Set rf source to test frequency, adjust level for no deflection on galvanometer. Read rf voltmeter. Difference from previous reading is the frequency response error.

2.8 Overload Characteristics of the Probes

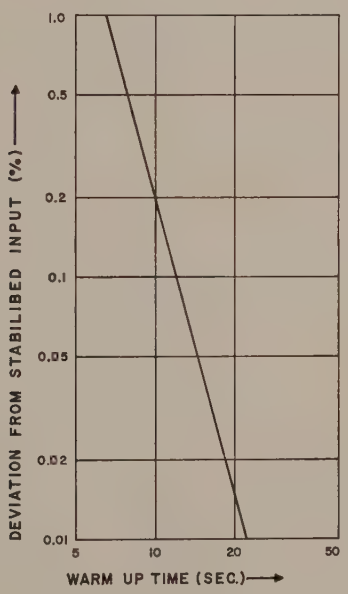
The thermocouple in all probes has a nominal rating of 5 mA. This current is passing through the thermocouple when the maximum voltage of the probe range is applied to a probe. A small overload up to 50% above this value

is permissible and will not cause damage to the thermocouple. *Overload over 50% of the maximum probe voltage will cause a burnout or permanent change* in the thermocouple, and should be avoided under any circumstances.

The Model 393 transfer unit is designed to supply dc and bucking voltages to cover normal probe ranges. If the input to the probe is outside the probe range, AC or DC BALANCE may not be possible. Thus, the probe cannot be used at voltages much above or below the specified ranges.

2.9 Warmup Time of the Thermocouple

The thermocouple output is determined by the thermocouple filament temperature. It will change until the filament and its supports reach a stable temperature. A typical warmup time is shown in the graph below.



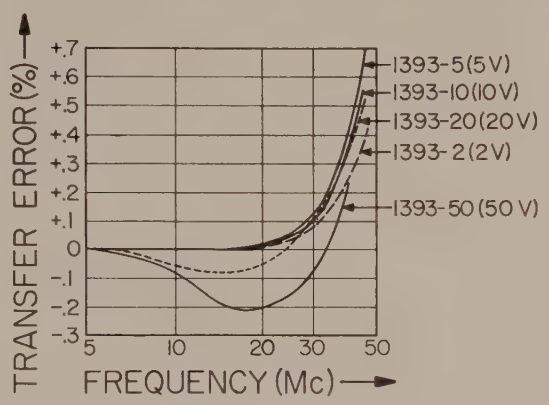
Graph 1. Thermocouple Warmup Characteristic.

In this graph, the error in measuring the input voltage is shown as a function of time after applying the voltage. The completely warmed up thermocouple is considered to give the correct indication. As shown in the graph, the measurement is over 0.1% in error when the AC BALANCE is achieved within 10 sec and over 0.01% when the balance is achieved within 20 sec. For utmost accuracy, a minimum of 30 sec warmup should be allowed before balancing the circuit.

Because of the thermocouple warmup time, transferring connection from the ac source to the dc source should be done as rapidly as possible. If the connection is done in a few seconds, a shorter warmup time, as indicated in graph 1 is needed for dc balance.

2.10 Frequency Response of the Probes

The probes have a frequency dependent transfer error. Error for typical probe is shown in the graph below.



Graph 2. Typical Frequency Response of Probes.

This error is a function of the components and their location within the particular probe. A given probe's response may differ from the typical response shown above, but will stay the same throughout the life of the probe. Therefore, the frequency response of a probe may be measured and a correction applied when most accurate measurements are needed. Probes may be calibrated by NBS to an accuracy of $(3 + f)/100(\%)$ where f is the calibration frequency in megacycles.

2.11 Precision of Measurement is determined by the care used in setting the BALANCE AC and DC controls for minimum galvanometer deflection. With very careful setting of the controls, a precision (repeatability) of 0.02 - 0.05% may be achieved. If a measurement accuracy on the same order is desired, more than one determination should be made. At least 4 determinations, or two for each polarity of dc, are recommended.

2.12 External Influences

Complete shielding of the probes and transfer unit, with proper grounding of the signal and thermocouple circuit, will insure correct results in normal laboratory environments. However, excessive ground currents, or very strong rf fields may introduce errors in measurements, and should be avoided if the full accuracy of the instrument is to be realized.

3. CIRCUIT DESCRIPTION

3.1 Principle of Measurement

The Model 393 Transfer Voltmeter utilizes a principle by which the value of an unknown ac or rf voltage is transferred to an rms equivalent dc voltage which may be measured accurately by conventional dc instruments.

The Transfer Voltmeter consists of the Model 393 Transfer Unit and a set of Model 1393 Probes. The Transfer Unit houses the galvanometer, batteries, controls, switches and accurate dividers. The probe consists of a stable compensated measuring resistor and a thermocouple. The basic schematic of the probe and transfer unit is shown below.

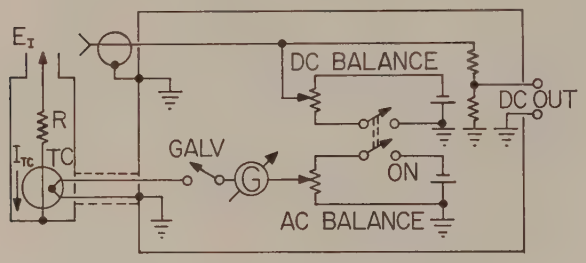


Figure 5. Simplified Circuit Diagram.

The probe is designed so that its transfer impedance Z_T:

$$Z_T := \frac{E_i}{I_{TC}}$$

E_i = Voltage applied to the probe
I_{TC} = Current through the thermocouple

is constant over a frequency range up to 30 Mc. It equals the combined dc resistance of the resistor R and the thermocouple TC.

If the transfer impedance of the probe is constant, a constant voltage, independent of frequency, exists at the probe input when a constant current is measured through the thermocouple. This condition permits comparing an ac voltage with a dc voltage. For comparison, an ac voltage is fed to the probe and the thermocouple current registered by bucking it out. Next a dc voltage is fed to the probe. Its value is changed until the same thermocouple output is observed, in which case the dc voltage equals the rms value of the ac voltage. The dc voltage may be measured with an accurate dc device.

3.2 The Model 1393 Probe consists of a stable measuring resistor and a high frequency thermocouple. The resistor is mounted coaxially into a cylindrical tube, the diameter of which is designed to provide a constant transfer impedance over a wide frequency range. The thermocouple is a high frequency type with an insulated couple junction. To reduce hf pickup in the couple the thermojunction output circuit is completely shielded, and the thermocouple leads are formed to introduce a minimum loop area.

The higher value probes have measuring resistors which are compensated to provide a uniform transfer impedance. A typical transfer impedance response is shown on graph 2 (see paragraph 2.10).

The responses may vary slightly between different probes. For a given probe it will stay constant throughout the life of the probe if the components or their locations are not changed. Therefore an accurate calibration may be applied and the typical frequency response error corrected.

3.3 The Model 393 Transfer Unit has three separate circuits:

3.3.1 The Bucking (BALANCE AC) and the galvanometer circuit consists of the galvanometer M1, Galv. Switch S3, coarse and fine BALANCE AC controls R15, R23 with associated resistors and the battery B1.

With the controls R15 and R23 the battery voltage is divided to 1 mV to 7 mV to equal the thermocouple output in which case no deflection is observed in the galvanometer when Galv. Switch S3 is depressed. The circuit is designed to give the proper damping resistance to the galvanometer and to so provide the fastest response.

3.3.2 The DC Supply (BALANCE DC) Circuit provides the dc transfer voltage for the 2 and 5 V ranges. It consists of batteries B3 to B7, controls R22 and R25, accurate dividers R13-R17 and the switch S4. S4 is located at the bottom of the probe holder. It is normally in the 2 V position, so that 2 V is applied to every probe inserted into the holder. When a 5 V probe, which has two extra posts on the front face, is inserted into the holder, the switch S4 is activated and 5 V is applied to the probe.

The dc voltage may be adjusted with controls R25 and R22. The accurate dividers R16, R17 in the 2 V range, and R13, R14 in the 5 V range will divide the voltage by 1 to 2 or 1 to 5 so that a maximum of 1 V appears across the DC OUT terminals.

3.3.3 The DC Supply Switch S2 switches all the batteries off, or reverse the polarity of the voltage to the probe in REVERSE position.

3.3.4 The Galvanometer Light Circuit consists of battery B2 and switch S1 which switches the galvanometer light on in ON position. In OFF position it shorts the galvanometer to avoid damage to the delicate moving system during transportation.

4. MAINTENANCE AND SERVICE

The Model 393 is constructed of the best commercial components which are carefully inspected and checked. With the exception of the batteries it contains only passive components which should have very long lives if not overloaded or misused. The Transfer Voltmeter needs no adjustments, only infrequency calibration checks (once in 1 to 2 years). The periodic maintenance consists of checking and replacing the batteries, possible change of galvanometer light and possible adjustment of the galvanometer light beam position.

Refined service and comprehensive calibration requires accurate and special equipment normally not available to the user. Therefore if trouble develops which cannot be corrected by the simplified methods outlined here or when accurate recalibration of the instrument is needed, it is recommended that the voltmeter be returned to Ballantine Laboratories for service and/or recalibration. If it should become necessary to return the instrument or any part thereof to Ballantine Laboratories, Inc. for examination or servicing, at least 4 inches of packing material should be placed around all sides of the instrument to prevent damage during shipment. Ship via Railway Express or motor truck. A letter describing the trouble or desired service will help our Service Department greatly and insure a fast return.

4.1 The Galvanometer Light Beam may need adjustment when the light beam does not rest in the middle of the scale. This may happen after a strong shock, transportation, or overload of the galvanometer. The light beam's exact location on the scale is not important and does not affect the measuring accuracy. It is recommended that the light beam be set exactly to some scale division which makes the observation of small deflections easier.

4.1.1 — For small adjustments the ground glass may be shifted to right or left by depressing the scale slightly and moving it to the right or left.

4.1.2 — For coarse adjustments, the round knob on the upper part of the galvanometer may be rotated until the light beam comes close to the desired position, then the ground glass can be shifted for fine adjustment.

4.2 Changing the Galvanometer Light Battery B2 is required when the light appears dim or fades after short use. To accomplish the change:

4.2.1 — Remove the four #6 nickel plated binder head screws from the panel. Lift up the panel, disconnect the battery plug from the terminal board.

4.2.2 — Loosen the two #4 nickel plated binder head screws from the battery holder on the rear of the case. Unplug and replace the battery.

4.3 Changing Galvanometer Light Bulb is required when the light spot does not appear after switching the GALV toggle switch to ON. Before changing the light, remove the instrument from its case (4.2.1), and inspect the condition of the batteries, and check the battery plug contacts. If this does not correct the situation, the bulb should be changed. To do so:

4.3.1 — Pull the bulb socket out of the bulb holder. Replace the bulb with the spare bulb stored on the frame of the galvanometer.

New bulbs may be ordered. Ask for Selected Galvanometer Bulb, Rubicon Cat. No. 3089, from the Rubicon Company, Ridge Ave. at 35th Street, Philadelphia 32, Pennsylvania or from Ballantine Laboratories.

4.3.2 — After changing the bulb, adjust the position of the bulb holder until a clear and sharp image of the hairline appears on the ground glass.

4.4 Changing Mercury Batteries B1 and B3-B7 is necessary when the AC BALANCE or DC BALANCE adjustment shows a tendency to shift during measurement. This condition may occur after approximately 400-500 hours of operation, or after batteries are stored for over a year.

For replacement, remove the instrument from the case (4.2.1). Unplug the battery cable and pull out the mercury batteries from their clamps. Insert the new batteries with the battery tabs pointed to the right.

4.5 Servicing Model 1393 Probes should not be needed if the probes are handled within their limits. However, the thermocouple in the probe is a delicate component which may be burned out when overloaded. A moderate shock, or dropping of the probe, may also damage the thermocouple.

The thermocouple may be replaced with UHF Type 5 mA thermocouple made by the Best Co., available from Ballantine Laboratories under Part No. 2951. If the replacement is done carefully so that the position of the thermocouple and the resistor is not altered, the frequency response of the probe will remain within the stated original limits.

Replacement of the thermocouple:

4.5.1 — Remove the red Ballantine Emblem from the nameplate at the rear face of the probe. Punch a ¼" diameter hole through the center, which was covered by the Ballantine emblem. With a hot fine-tip soldering iron, heat up the solder-joint between the thermocouple lead (coaxial wire) and the crosswire. Push the thermocouple lead away from the crosswire to open the solder connection.

4.5.2 — Remove the six flat head screws which hold the rear cover. Remove the cover. With a hot soldering iron heat and open the connections from the thermocouple to the dc output jack. Observe that the lead marked with a red dot is connected to pin A of the connector.

4.5.3 — Remove the 4 Phillips head screws from the GR Type 847 connector at the input of the probe. Carefully pull out the thermocouple and resistor assembly through the connector opening.

4.5.4 — Replace the thermocouple. Use a jig to make sure that the replacement thermocouple is located in the same relative position as the original thermocouple. Observe that the dc output lead marked with a red dot is on the same side as in the original thermocouple. Use a hot soldering iron and the shortest possible soldering time to avoid overheating the thermocouple.

4.5.5 — Reassemble the probe in reverse order.

4.6 Trouble Shooting Chart

In the following chart the symptoms of possible component or part failure are described:

SYMPTOM	POSSIBLE CAUSE	PERTINENT SECTION
Lightspot does not show	Light beam out of scale. Battery B2 dead or disconnected. Galvanometer bulb burned out.	4.1 4.2 4.3
BALANCE AC setting drifts	Measured AC voltage is changing. Battery B1 old.	 4.4
BALANCE DC setting drifts	Batteries B2-B7 old.	4.4
Lightspot off center of the scale	Galvanometer beam shifted.	4.1
Lightspot illumination uneven, hairline not sharp or vertical	Galvanometer bulb holder misadjusted.	4.3
BALANCE AC control has no effect, lightspot swings freely when GALV pushbutton depressed	Galvanometer circuit interrupted, bad connection in probe cable or plug. Burned out thermocouple.	 4.5
BALANCE AC control has no effect, lightspot stable when GALV pushbutton depressed	Battery B1 dead or disconnected. Battery circuit interrupted.	 4.4
BALANCE AC cannot be reached	Input voltage outside the probe range. Battery B1 old. Probe has been overloaded.	4.4 4.5
BALANCE DC cannot be reached		
2 V range:	Battery B3, B4 old. Probe has been overloaded.	
5 V range:	Battery B3 to B7 old. Probe has been overloaded. Probe is not depressed to the bottom of the holder. Swith S4 defective.	4.4 4.5

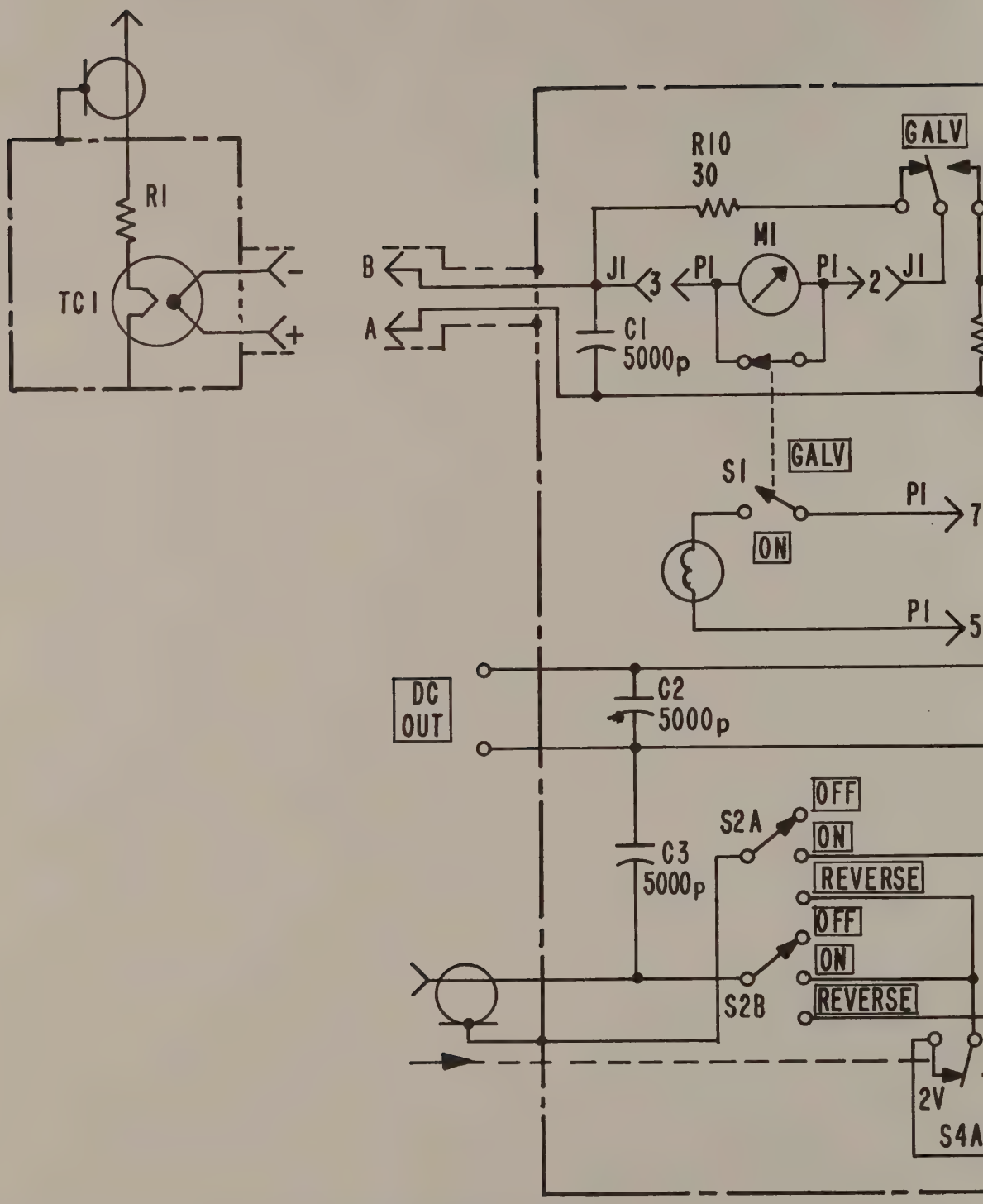
5. REPLACEMENT PARTS LIST

REFER TO MODEL 393 CIRCUIT DIAGRAM, ISSUE MB-1659C

B. L. Part No.	*Circuit Symbol*	*Capacitors*	*Manufacturer*
2538	C1	5,000 pF, Type BYA10D1M	Cornell-Dubilier
2538	C2	5,000 pF, Type BYA10D1M	Cornell-Dubilier
2538	C3	5,000 pF, Type BYA10D1M	Cornell-Dubilier
		Resistors	
1360	R10	30 ohms, Type CP-½, 2%	Hi-Q Aerovox
1868	R11	10 ohms, Type 12E, 1%	Shallcross
1869	R12	32 ohms, Type 12E, 1%	Shallcross
1867	R13	1,125 ohms, Type P12, ¼%	Shallcross
1630	R14	4,500 ohms, Type P12, ¼%	Shallcross
1841	R15	500 ohms, Type 973J	General Radio
1630	R16	4,500 ohms, Type P12, ¼%	Shallcross
1630	R17	4,500 ohms, Type P12, ¼%	Shallcross
1870	R18	5.5 ohms, Type 12E, 1%	Shallcross
1325	R19	7,500 ohms, Type CP-½, 1%	Hi-Q Aerovox
1871	R20	170 ohms, Type 12E, 1%	Shallcross
1335	R21	2,000 ohms, Type CP-½, 1%	Hi-Q Aerovox
1840	R22A*	1,000 ohms, Type 973K-L	General Radio
	R22B*	2,000 ohms, Type 973K-L	General Radio
1839	R23	10 ohms, 3 Turn Helipot CR10L.5	Beckman
1335	R24	1,000 ohms, Type CP-½, 1%	Hi-Q Aerovox
1839	R25	10 ohms, 3 Turn Helipot CR10L.5	Beckman

*Both units "gang" mounted on one shaft.

		Other Components	
3095	B-1, 3, 4, 5, 6, 7	Battery, Mercury, Type RM4RTZ	Mallory
3091	B-2	Battery, Type A4	Ray-O-Vac
2851	G	Galvanometer, Type 3080AL (Modified)	Rubicon
3280	S2	Switch, Special	Ballantine
4495	S3	Key, Galvanometer, Type SP-156-L	Rubicon
3281	S4	Switch, Type 4006	Switchcraft
	PROBE, 1-2 Volt		
2688	R1	310 ohm Resistor, 1%, Special	Ballantine
2951	TC1	5 mA Thermocouple, Type UHF	Ballantine
	PROBE, 2-5 Volt		
2689	R1	900 ohm Resistor, 1%, Special	Ballantine
2951	TC1	5 mA Thermocouple, Type UHF	Ballantine
	PROBE, 5-10 Volt		
2690	R1	1,900 ohm Resistor, 1%, Special	Ballantine
2951	TC1	5 mA Thermocouple, Type UHF	Ballantine
	PROBE, 10-20 Volt		
2691	R1	3,900 ohm Resistor, 1%, Special	Ballantine
2951	TC1	5 mA Thermocouple, Type UHF	Ballantine
	PROBE, 20-50 Volt		
2692	R1	10,000 ohm Resistor, 1%, Special	Ballantine
2951	TC1	5 mA Thermocouple, Type UHF	Ballantine



CAPACITORS: NOT MARKED – MICROFARADS (10^{-6}F)
P ——— PICOFARADS (10^{-12}F)
RESISTORS: NOT MARKED – OHMS (Ω)
K ——— KILOHMS (10^{3} Ω)
M ——— MEGAOHMS (10^{6} Ω)
VOLTAGES: NOT MARKED —— VOLTS (V)
mV ——— MILLIVOLTS (10^{-3}V)

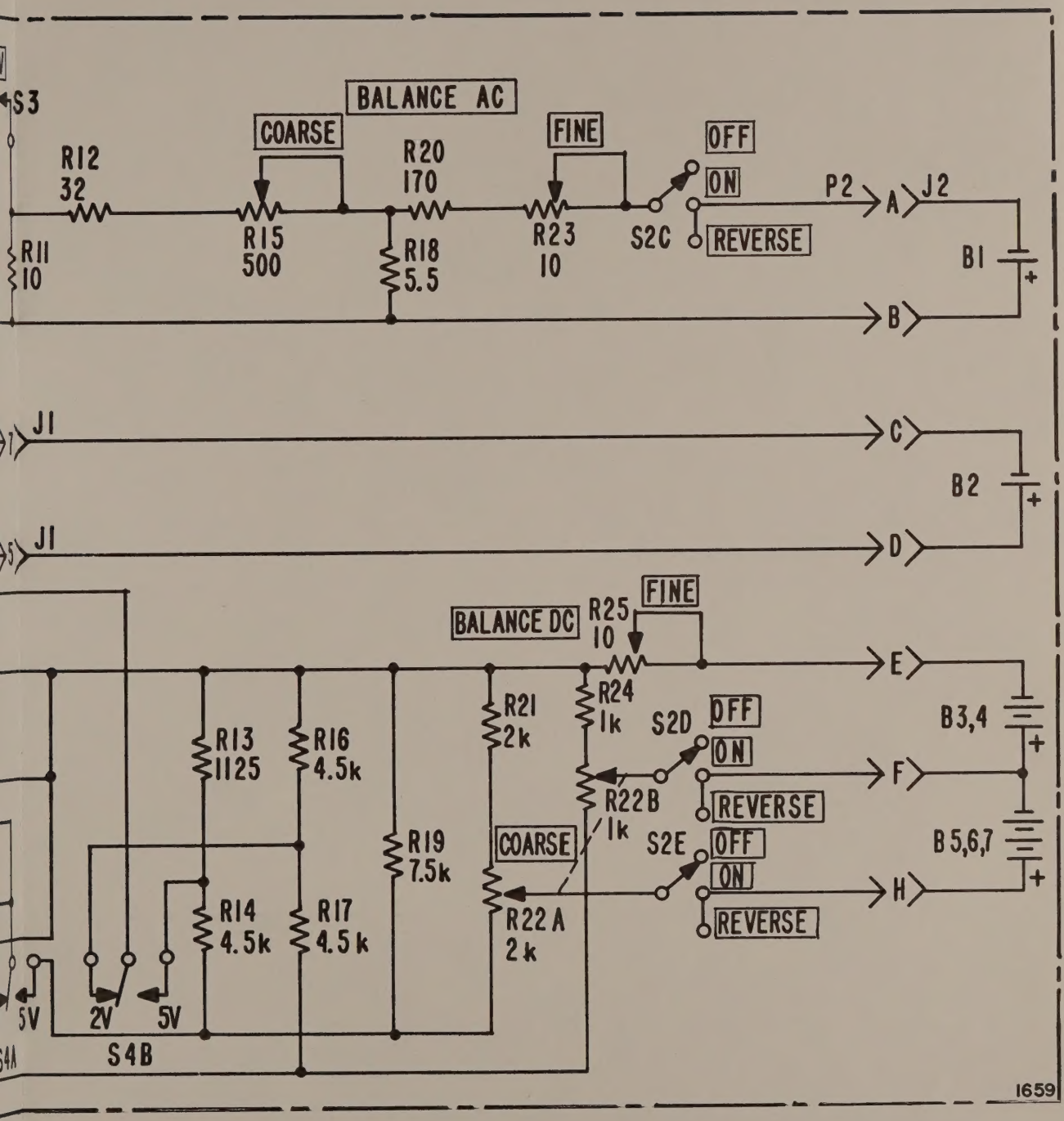


FIGURE 6 — CIRCUIT DIAGRAM — ISSUE MB-1659C
MODEL 393 HIGH FREQUENCY TRANSFER VOLTMETER

BALLANTINE LABORATORIES, INC.
BOONTON, N. J.

MP MASTER
MA31980